CLAIMS

What is claimed is:

1. A method, comprising the step of:

separating one or more fetal heart component signals from heart signal information obtained from a pregnant female based on singular value decomposition.

2. The method of claim 1, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the step of:

employing one or more analog-to-digital converters to digitize the heart signal information upon receipt of the heart signal information.

3. The method of claim 1, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the step of:

employing one or more filtering components to reduce one or more amplitudes of one or more components of the heart signal information.

4. The method of claim 3, wherein the step of employing the one or more filtering components to reduce the one or more amplitudes of the one or more components of the heart signal information comprises the step of:

employing one or more non-linear filters and one or more non-linear inverse filters to reduce the one or more amplitudes of the one or more components of the heart signal information.

5. The method of claim 1, wherein the heart signal information comprises the one or more fetal heart component signals, one or more maternal heart component signals, and one or more noise component signals, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the steps of:

determining one or more blind separators based on singular value decomposition; and

employing the one or more blind separators to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals.

6. The method of claim 1, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the steps of:

employing one or more cepstral transformation components to identify one or more noise components in the one or more fetal heart component signals;

reducing one or more amplitudes of the one or more noise components in the one or more fetal heart component signals to change the one or more fetal heart component signals into one or more reduced-noise fetal heart component signals; and

employing one or more inverse cepstral transformation components to output one or more of the one or more reduced-noise fetal heart component signals.

7. The method of claim 1, wherein the heart signal information comprises the one or more fetal heart component signals, one or more maternal heart component signals, and one or more noise component signals, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the steps of:

employing one or more analog-to-digital converters to digitize the heart signal information upon receipt of the heart signal information;

employing one or more non-linear filters and one or more non-linear inverse filters to reduce one or more amplitudes of one or more components of the heart signal information;

determining one or more blind separators based on singular value decomposition; and

employing the one or more blind separators to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals.

8. The method of claim 7, further comprising the steps of:

employing one or more cepstral transformation components to identify one or more noise components in the one or more fetal heart component signals;

reducing one or more amplitudes of the one or more noise components in the one or more fetal heart component signals to change the one or more fetal heart component signals into one or more reduced-noise fetal heart component signals; and

employing one or more inverse cepstral transformation components to output one or more of the one or more reduced-noise fetal heart component signals.

9. The method of claim 7, further comprising the step of:

employing a high pass filter with a cut-off frequency that is one-third or less of the average frequency of a maternal heart rate to remove effects of time-variations in a long term mean of the heart signal information between maternal heart beats.

10. The method of claim 7, further comprising the step of:

employing one or more stages of differencing between successive samples of the heart signal information to remove effects of time-variations in a long term mean of the heart signal information between maternal heart beats.

11. The method of claim 7, wherein the one or more blind separators comprise a multi-step iterative separator, wherein the step of employing the one or more blind separators to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals comprises the steps of:

passing a set of estimated separation signals from a first separation iteration to a next separation iteration;

creating cross-correlations of each estimated separation signal of one separation iteration with each other estimated separation signal of the one separation iteration after each separation iteration;

evaluating an absolute value of the cross-correlations; and

outputting the outcome of the multi-step iterative separator once a maximal absolute value of the cross correlations is below a pre-determined threshold value.

12. The method of claim 11, wherein the step of outputting the outcome of the multi-step iterative separator once the maximal absolute value of the cross correlations is below the pre-determined threshold value comprises the step of:

entering the set of estimated separation signals as initialization parameters to an artificial neural network that iteratively outputs incremental changes to the initialization parameters until the maximal absolute value is below the pre-determined threshold value.

13. The method of claim 7, wherein the one or more blind separators comprise a multi-step iterative separator, wherein the step of employing the one or more blind separators to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals comprises the steps of:

passing a set of estimated separation signals from a first separation iteration to a next separation iteration;

creating cross-correlations of each estimated separation signal of one separation iteration with each other estimated separation signal of the one separation iteration after each separation iteration;

evaluating an absolute value of the cross-correlations; and

outputting the outcome of the multi-step iterative separator once a sum of absolute values of the cross correlations is below a pre-determined threshold value.

14. The method of claim 13, wherein the step of outputting the outcome of the multi-step iterative separator once the sum of the absolute values of the cross correlations is below the pre-determined threshold value comprises the step of:

entering the set of estimated separation signals as initialization parameters to an artificial neural network that iteratively outputs incremental changes to the initialization parameters until the sum of the absolute values is below the pre-determined threshold value.

15. The method of claim 1, wherein the heart signal information comprises multi-channel information of mixtures in different mixing combinations of at least three different types of signals, one being maternal electrocardiogram, one being fetal electrocardiogram, and one being noise;

wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the steps of:

employing at least three channels to obtain the heart signal information;

placing a first pair of electrodes on a chest of the pregnant female; and

placing a second pair of electrodes on an abdomen or lower back of the pregnant female to obtain a portion of the heart signal information closer to a heart of the fetus.

16. The method of claim 1, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on singular value decomposition comprises the steps of:

computing a singular value decomposition of a covariance matrix of the heart signal information to yield a set of output signals;

computing a delay parameter to minimize an absolute value of cross-correlations between the set of output signals;

taking a singular value decomposition of the sum of a covariance matrix of the set of output signals; and

taking a singular value decomposition of a transpose of the covariance matrix of the set of output signals to yield a separated output estimate of the one or more fetal heart component signals.

17. The method of claim 16, further comprising the step of:

passing the separated output estimate through a blind adaptive filter to identify parameters of the separated output estimate, wherein the blind adaptive filter uses the parameters to adapt a filtering algorithm to reduce noise of the separated output estimate.

18. The method of claim 17, further comprising the step of:

reentering outputs of the blind adaptive filter into a singular value decomposition to undergo another round of separation.

19. The method of claim 17, wherein the heart signal information comprises the one or more fetal heart component signals, one or more maternal heart component signals, and one or more noise component signals;

wherein the step of reentering the outputs of the blind adaptive filter into the singular value decomposition to undergo another round of separation comprises the steps of:

determining one or more blind separators based on singular value decomposition; and

employing the one or more blind separators to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals.

20. An apparatus, comprising:

one or more processor components that separate one or more fetal heart component signals from heart signal information obtained from a pregnant female based on singular value decomposition.

21. The apparatus of claim 20, wherein one or more of the one or more processor components employ one or more analog-to-digital converters to digitize the heart signal information in preparation for execution of one or more signal processing procedures by the one or more of the one or more processor components.

22. The apparatus of claim 21, wherein the one or more signal processing procedures comprise one or more filtering procedures;

wherein the one or more of the one or more processor components employ the one or more analog-to-digital converters to digitize the heart signal information in preparation for execution of the one or more filtering procedures by the one or more of the one or more processor components;

wherein the one or more of the one or more processor components employ one or more non-linear filters and one or more non-linear inverse filters to reduce one or more amplitudes of one or more components of the heart signal information.

23. The apparatus of claim 21, wherein the one or more signal processing procedures comprise one or more filtering procedures;

wherein the one or more of the one or more processor components employ the one or more analog-to-digital converters to digitize the heart signal information in preparation for execution of the one or more filtering procedures by the one or more of the one or more processor components;

wherein the one or more of the one or more processor components employ one or more blind adaptive filters to reduce one or more amplitudes of the heart signal information.

24. The apparatus of claim 20, wherein the heart signal information comprises a plurality of electrocardiogram signals;

wherein one or more of the one or more processor components record the plurality of electrocardiogram signals through employment of three or more electrode pairs of:

an abdominal electrode pair;

a chest electrode pair; and

a thoracic electrode pair.

25. The apparatus of claim 20, wherein the heart signal information comprises a plurality of magnetocardiogram signals;

wherein one or more of the one or more processor components record the plurality of magnetocardiogram signals through employment of three or more sensors of:

an abdominal sensor;

a chest sensor; and

a thoracic sensor.

26. The apparatus of claim 20, wherein one or more of the one or more processor components separate one or more of the one or more fetal heart component signals from the heart signal information based on singular value decomposition at any selected time at or after a twelfth week of pregnancy of the pregnant woman.

27. An article, comprising:

one or more computer-readable signal-bearing media; and

means in the one or more media for separating one or more fetal heart component signals from heart signal information obtained from a pregnant female based on singular value decomposition.

28. A method, comprising the steps of:

employing one or more filters to extract one or more fetal heart component signals from heart signal information obtained from a pregnant female;

separating the one or more fetal heart component signals from the heart signal information based on independent component analysis; and

employing one or more blind adaptive filtering components to reduce noise in the one or more fetal heart component signals.

29. The method of claim 28, wherein the one or more filters comprise a non-linear filter and a non-linear inverse filter, wherein the step of employing the one or more filters to extract the one or more fetal heart component signals from the heart signal information obtained from the pregnant female comprises the steps of:

employing the non-linear filter and the non-linear inverse filter to reduce one or more amplitudes of the heart signal information obtained from the pregnant female; and

employing one or more analog-to-digital converters to digitize the heart signal information upon receipt of the heart signal information.

30. The method of claim 28, wherein the step of employing one or more blind adaptive filtering components to reduce noise in the one or more fetal heart component signals comprises the step of:

operating the one or more blind adaptive filtering components in one or more of a frequency domain, a cepstral domain, and/or a wavelet transform domain.

31. The method of claim 30, wherein the one or more blind adaptive filtering components operate in the cepstral domain, wherein the step of employing the cepstral analysis to reduce noise in the one or more fetal heart component signals comprises the steps of:

employing a cepstral transformation, a cepstral filtration, and an inverse cepstral transformation to reduce the noise in the one or more fetal heart component signals;

employing the cepstral transformation to identify one or more noise components in the one or more fetal heart component signals;

employing the cepstral filtration to reduce one or more amplitudes of the one or more noise components in the one or more fetal heart component signals to change the one or more fetal heart component signals into one or more reduced-noise fetal heart component signals; and

employing the inverse cepstral transformation to output one or more of the one or more reduced-noise fetal heart component signals.

32. The method of claim 28, wherein the heart signal information comprises the one or more fetal heart component signals, one or more maternal heart component signals, and one or more noise component signals, wherein the step of separating the one or more fetal heart component signals from the heart signal information obtained from the pregnant female based on independent component analysis comprises the steps of:

employing one or more analog-to-digital converters to digitize the heart signal information upon receipt of the heart signal information;

employing one or more non-linear filters and one or more non-linear inverse filters to reduce one or more amplitudes of the heart signal information;

employing independent component analysis to separate the one or more fetal heart component signals from the one or more maternal heart component signals and the one or more noise component signals;

employing one or more cepstral transformation components to identify one or more noise components in the one or more fetal heart component signals;

reducing one or more amplitudes of the one or more noise components in the one or more fetal heart component signals to change the one or more fetal heart component signals into one or more reduced-noise fetal heart component signals; and

employing one or more inverse cepstral transformation components to output one or more of the one or more reduced-noise fetal heart component signals.

33. An apparatus, comprising:

one or more processor components that cause one or more filters to extract one or more fetal heart component signals from heart signal information obtained from a pregnant female;

wherein a first one or more of the one or more processor components separate the one or more fetal heart component signals from the heart signal information based on independent component analysis;

wherein a second one or more of the one or more processor components employ one or more blind adaptive filtering components to reduce noise in the one or more fetal heart component signals.

34. The apparatus of claim 33, wherein the one or more filters comprise a non-linear filter and a non-linear inverse filter;

wherein a third one or more of the one or more processor components cause the non-linear filter and the non-linear inverse filter to reduce one or more amplitudes of the heart signal information obtained from the pregnant female.

35. The apparatus of claim 33, wherein the second one or more of the one or more processor components employ cepstral transformation to identify one or more noise components in the one or more fetal heart component signals;

wherein the second one or more of the one or more processor components employ cepstral filtration to reduce one or more amplitudes of the one or more noise components in the one or more fetal heart component signals to change the one or more fetal heart component signals into one or more reduced-noise fetal heart component signals;

wherein the second one or more of the one or more processor components employ inverse cepstral transformation to output one or more of the one or more reduced-noise fetal heart component signals.

36. The apparatus of claim 33, wherein the heart signal information comprises a plurality of electrocardiogram signals;

wherein a third one or more of the one or more processor components record the plurality of electrocardiogram signals through employment of three or more electrode pairs of:

an abdominal electrode pair;

a chest electrode pair; and

a thoracic electrode pair.

37. The apparatus of claim 33, wherein the heart signal information comprises a plurality of magnetocardiogram signals;

wherein a third one or more of the one or more processor components record the plurality of magnetocardiogram signals through employment of three or more sensors of:

an abdominal sensor;

a chest sensor; and

a thoracic sensor.

38. The apparatus of claim 33, wherein the one or more blind adaptive filtering components operate in one or more of a frequency domain, a cepstral domain, and/or a wavelet transform domain.

39. An article, comprising:

one or more computer-readable signal-bearing media;

means in the one or more media for employing one or more filters to extract one or more fetal heart component signals from heart signal information obtained from a pregnant female;

means in the one or more media for separating the one or more fetal heart component signals from the heart signal information based on independent component analysis; and

means in the one or more media for employing a cepstral analysis to reduce noise in the one or more fetal heart component signals.

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